Spider
Engineering
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PROTOTYPE FURNACE CONSTRUCTION PHASE IV

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PROTOTYPE FURNACE CONSTRUCTION PHASE IV

Final Report

by

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for

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CANMET

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1.0) INTRODUCTION

The following report documents a project to develop and refine prototype high efficiency condensing gas furnaces. The project was undertaken by Spider Engineering Associates under contract to the Consumers' Gas Co. and the Department of Energy, Mines, and Resources. The furnace prototype development is a continuation of work performed by Spider Engineering, and the reader is referred to references 1, 2 and 3 to obtain a complete background regarding this project.

The furnace design utilizes a unique flue gas recirculation process which enables the use of a low temperature plastic heat exchanger to cool the combustion products into the condensing temperature regime [1,2]. The use of a plastic condensing heat exchanger provides a resistance to corrosion that is superior to that typical of metals. The design and assembly of the plastic heat exchanger is presented in detail in reference 3.

The objectives of the current work were twofold. The first objective was to examine and refine the recirculation loop. Prior to this project the recirculation loop utilized both an exhaust blower and a recirculation blower. The first objective, then, was to investigate the use of a single blower or double wheel blower in an effort to reduce cost, control complexity, and exhaust/recirculation interaction.

The second objective was to design and construct two prototype furnaces using the refined plastic heat exchanger described in reference 3 and the blower modifications finalized in the first part of this project.

2.0) FURNACE DESIGN AND OPERATION

2.1) FURNACE OPERATION

A process schematic of the prototype furnace is presented in figure 1. Room air and natural gas are burned in the lower section of the primary heat exchanger. The combustion flue gases pass through a mixing duct to the secondary condensing heat exchanger where the gases are cooled to approximately 40C. A portion of the cooled flue gas is recirculated to the mixing duct to cool the hot flue gases from the primary heat exchanger, while the remainder of the cooled flue gases are vented to atmosphere as exhaust. This recirculation and tempering process permits the use of low temperature plastic as the condensing heat exchanger material.

2.2) SEQUENCE OF OPERATION

The sequence of events typical of the operation of the prototype furnace will be described by following the furnace through a complete cycle. References will be made to the parts diagrams (figures 2,3) by noting the part number immediately after the component name. The furnace wiring diagram is presented in figure 4.

A demand for heat from the residence thermostat will start the recirculation/exhaust blower (PN 1). Operation of this blower is monitored by two pressure switches (PN 2, PN 3). If the blower exit pressure lies within an acceptable range, power is provided to the burner circuit. A heater relay provides a 15 second delay for pre-purge prior to pilot flame ignition.

Once the heater relay has activated the burner circuit, the pilot flame is ignited by an electronic ignition unit (PN 4). A temperature sensor near the pilot flame proves ignition and allows the main regulator (PN 5) to open providing gas to the main burners.

Upon satisfaction of the space heating requirement, the residence thermostat opens the burner circuit thereby shutting off the burners. The recirculation/exhaust blower remains operating for a fifteen second post-purge. The main blower remains running until the temperature control (PN 6) has cooled below the lower set point.

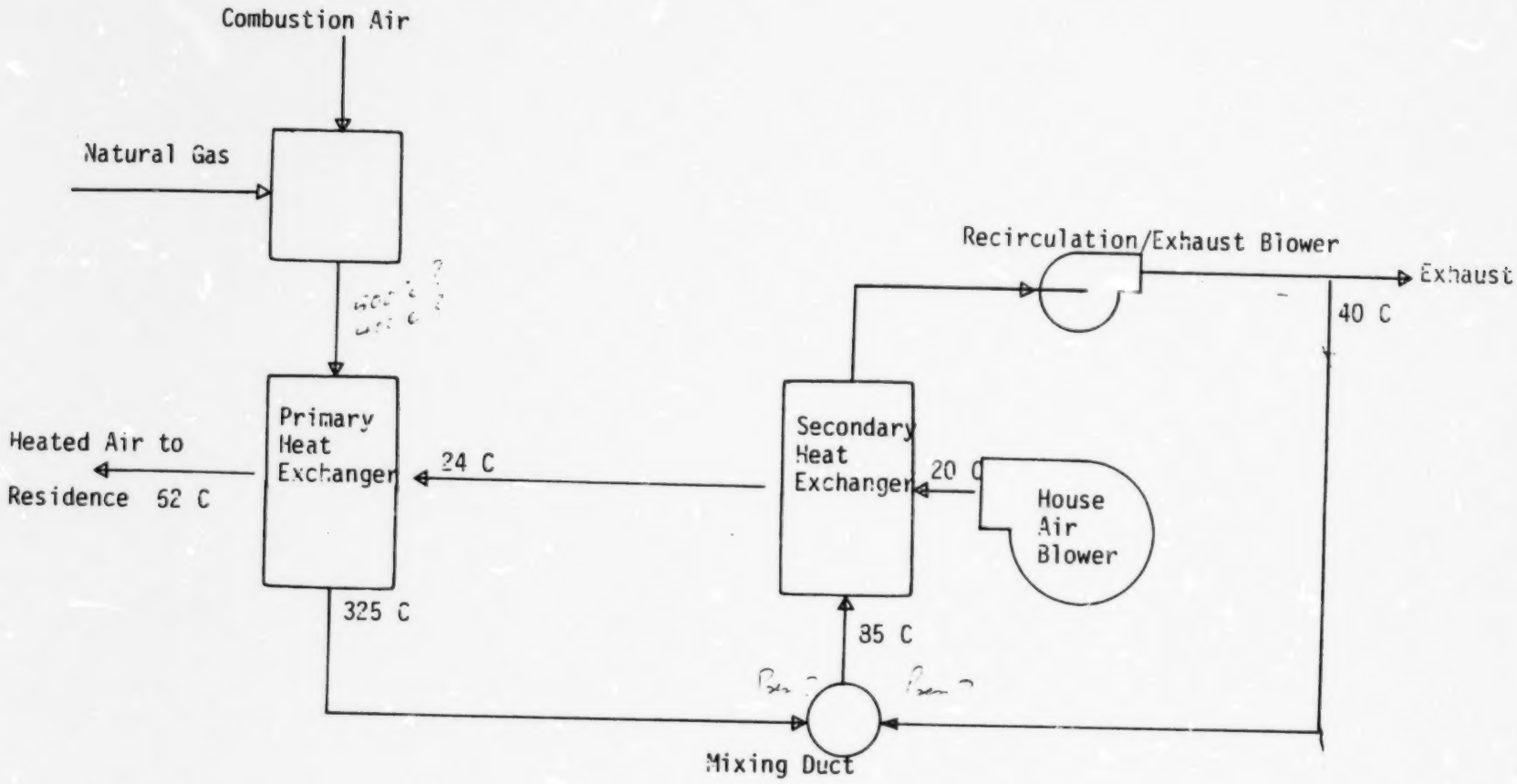
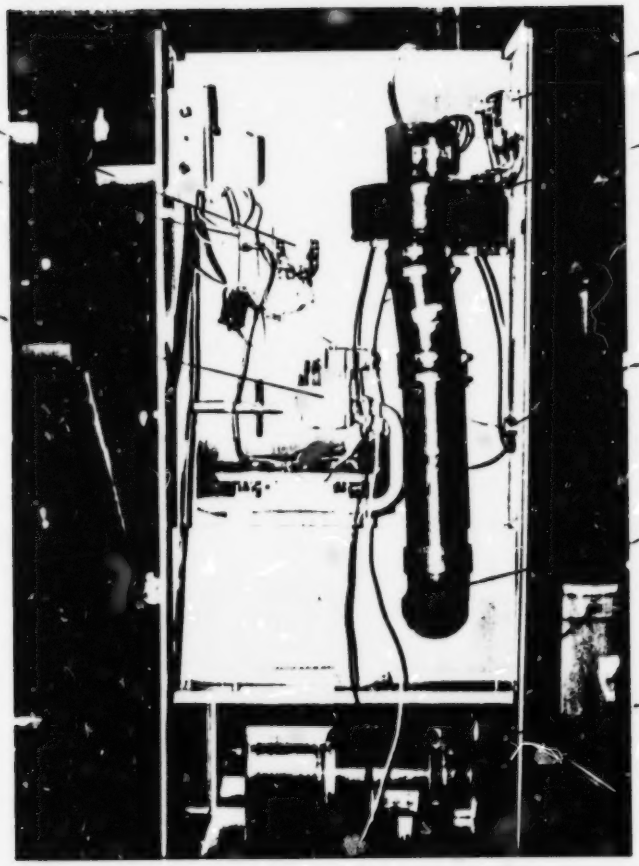
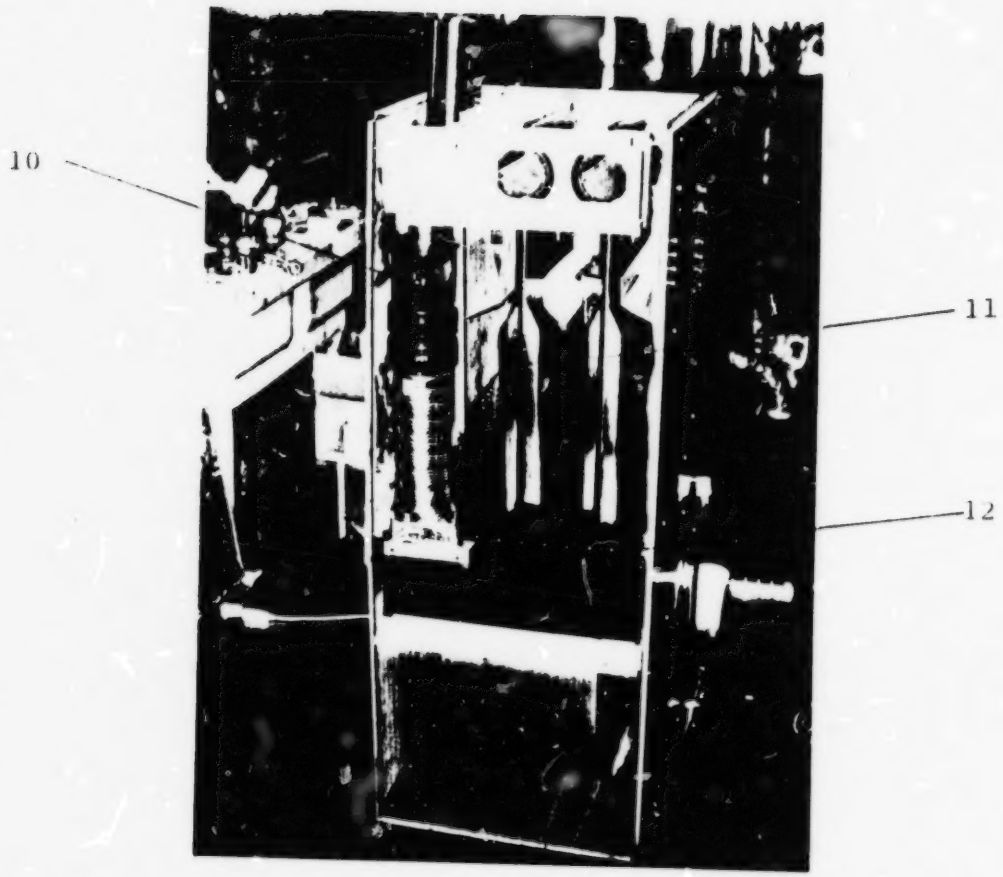


Figure 1: Furnace Process Schematic



1. Exhaust/Recirculation Blower
2. Pressure Switch
3. Pressure Switch
4. Electronic Ignition
5. Main Gas Regulator
6. Temperature Control
7. Spill Switch
8. Plastic Heat Exchanger Outlet
9. Main Blower

Figure 2: Furnace Parts Diagram



10. Mixing Duct
11. Primary Heat Exchanger
12. Plastic Heat Exchanger

Figure 3: Furnace Parts Diagram

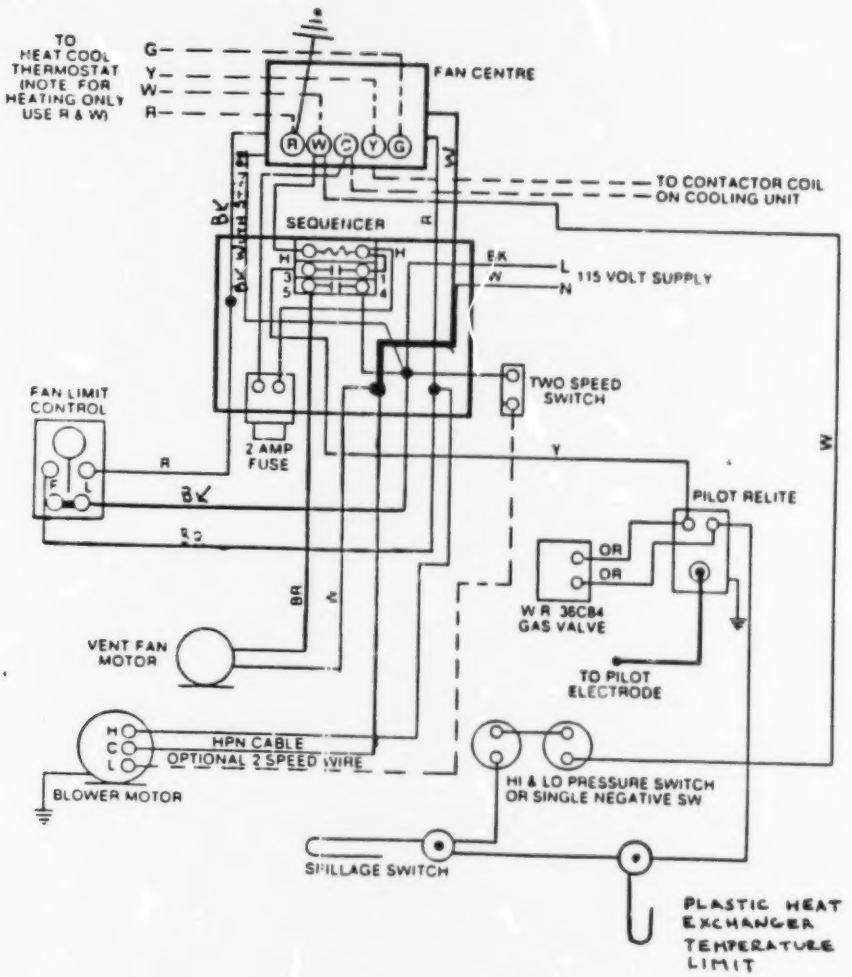


Figure 4: Furnace Wiring Diagram

2.3) SAFETY SYSTEMS

To ensure safe operation, the furnace is equipped with a number of devices to sense pressures and temperatures at specific locations within the furnace as described below, and to take appropriate control measures if the measurements indicate abnormal pressures and/or temperatures.

Protection against overheating is provided by two temperature controls. The temperature limit located at the flue gas inlet to the plastic heat exchanger has a set point of 110C with a manual reset. The temperature control located on the air side of the primary heat exchanger has an upper limit of 82C and does not require manual reset. Should either of these temperature controls rise above the set point the burners will be shut down followed by a flue gas post-purge.

The high pressure switch is connected to a pressure tap located immediately downstream of the recirculating/exhaust blower while the low pressure switch senses negative pressure on the inlet side of the above blower. The purpose of these pressure switches is to ensure an acceptable amount of flue gas exhaust flow. The burner circuit will not be complete unless the pressure is within the control range. If the pressure is less than the lower limit the furnace is operating with insufficient excess air for safe operation. If the exhaust flow is restricted, the measured pressure will rise above the high pressure limit and burner operation will be terminated.

As a further protection against exhaust flow restriction and a potential carbon monoxide health hazard, a spill switch has been installed at the burner opening. If the flow of exhaust gas should reverse, the hot gases will trip the spill switch (175C temperature limit) and interrupt burner operation. The spill switch must be manually reset, and hence ensures that the furnace receives attention and is serviced prior to restarting.

3.0) DISCUSSION

The prototype furnaces developed during this project incorporate a number of improvements over the previous design. The following section discusses these design improvements.

The overall dimensions of the furnace have been reduced, while service accessibility has been improved. This has been accomplished by mounting the recirculation/exhaust blower on the front panel rather than within the heat exchanger compartment. This has the added benefit of a lower temperature blower environment.

The number of furnace components has been reduced through the use of a single recirculation/exhaust blower. This has eliminated a blower, motor, and sail switch control, and hence reduces component cost while improving furnace reliability.

Furnace assembly has been simplified over the previous design. The plastic secondary heat exchanger slides in to position via side supports, and may be removed by detaching the condensate drain on the front, and the flue gas duct on the rear. The recirculation duct is assembled from standard ABS plastic components and flexible stainless steel pipe, The remainder of the furnace is assembled using standard furnace components in a conventional manner.

It should be noted that the manifolds on the plastic heat exchanger are not the recommended final design [3]. As discussed in the proposal [4] a moulded manifold was beyond the scope of this project, and hence the front and rear headers were custom fabricated.

4.0) PERFORMANCE CHARACTERISTICS

The performance characteristics of the prototype furnace were measured over the full range of possible operating conditions. The following section presents this performance data and discusses the exhaust/recirculation characteristics inherent in ths furnace design.

The steady state thermal efficiency of the furnace was 92 % at the following conditions; 18.75 kW firing rate, 28 C ambient temperature, 40 C exhaust temperature, 32 % excess air, 310 gm/hr condensate. It is not expected that the seasonal efficiency will differ appreciably from the steady state efficiency.

The furnace operating range is limited by two constraints. The excess air must not decrease below 25%, as poor combustion and/or spillage of flue gas from the burner compartment may occur. The second constraint is that the temperature at inlet to the plastic heat exchanger must not exceed 110 C. These constraints are not independent. Figure 5 illustrates the relationship between excess air and inlet temperature to the plastic heat exchanger. A decrease in exhaust flow (excess air) leads to an increase in recirculated flue gas which in turn results in cooler temperatures at inlet to the plastic heat exchanger.

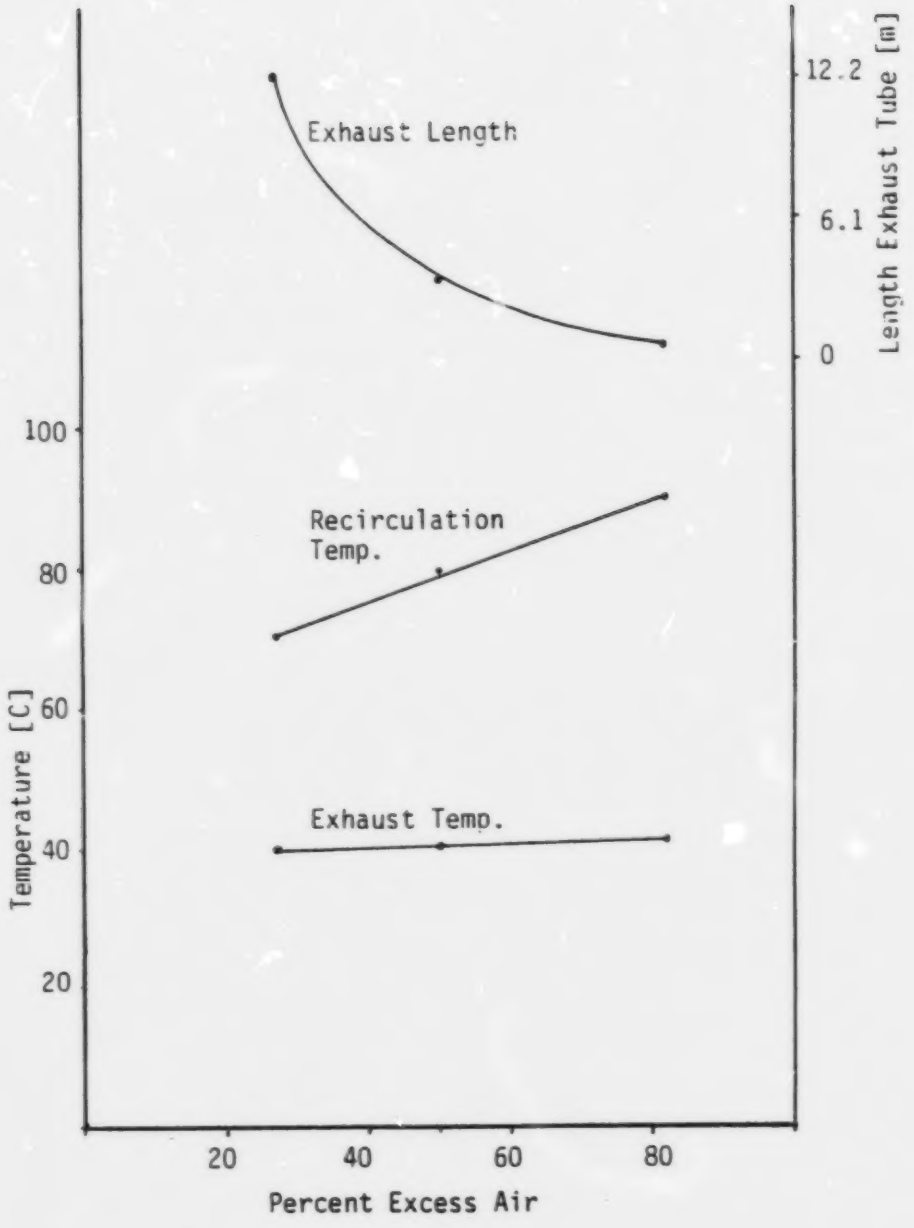


Figure 5: Performance Characteristics

5.0) CONCLUSIONS

The prototype furnaces produced during this project have a steady state efficiency of 92 %.

The single recirculation/exhaust blower design is capable of cooling the flue gas to below 40 C. This design represents an improvement in both reliability and component costs over the previous furnace design utilizing two blowers.

The refined plastic heat exchanger design is an improvement over the original Coroplast heat exchangers both in terms of seal quality and bond strength.

6.0) RECOMMENDATIONS

It is recommended that the prototype furnaces undergo field testing. The purpose of the tests should be to assess the plastic heat exchanger/recirculation loop design.

It is also recommended that alternate applications for the recirculation loop/plastic heat exchanger design be examined.

7.0) REFERENCES

1. Wright, J.L., Sullivan, H.F., "Conceptual Designs of High Efficiency Gas Furnaces", Spider Engineering Assoc. (Waterloo) Inc., 1981.

2 Wright, J.L., Briggs, R.J., Sullivan, H.F., "Prototype High Efficiency Furnace Development", Spider Engineering Assoc. (Waterloo) Inc., Feb. 1983.

3. Briggs, R.J., Sullivan, H.F., "Development and Refinement of a Plastic Heat Exchanger for Gas-Fired Furnaces", Spider Engineering Assoc. (Waterloo) Inc., Nov. 1984.

4. Briggs, R.J., Sullivan, H.F., "Proposal: Further Prototype Furnace Development", Spider Engineering Assoc. (Watrloo) Inc., Dec. 1984.

* All of the above reports were completed for The Consumers' Gas Co. Ltd. and the Department of Energy, Mines and Resources, CANMET.

APPENDIX A INSTALLATION INSTRUCTIONS

1. Attach natural gas supply. Do not adjust gas regulator.

2. Mount filter for house air return through side of furnace at bottom.

3. Mount plenum. Check that the static pressure rise through filter, furnace, and plenum is 0.25 inches water column (nominal setting).

4. Mount exhaust tubing to exhaust port. Do not exceed the equivalent of 40 feet [12.2 m] of 3 inch diameter exhaust tube.

5. Increase or decrease the exhaust restriction such that the furnace operates at approximately 40 % excess air. A sampling port for combustion measurement is provided at the exit of the primary heat exchanger.

APPENDIX B CONSTRUCTION DETAILS

B1.0) PLASTIC HEAT EXCHANGER

The plastic heat exchanger was assembled using the Emabond electro-magnetic welding process described in reference 3. The gap between sheets in the heat exchanger must be greater than 0.125 inches to avoid excessive pressure drop across the air side. The prototype units were assembled with a 0.25 inch gap between sheets. Figures B1, B2, B3, and B4 present the electro-magnetic welding process.

B2.0) RECIRCULATION/EXHAUST BLOWER

The recirculation/exhaust blower is assembled from the following components.

- Torin housing
- Hart and Cooley Ltd. blower wheel number AA 610 215-2 (6 1/4 " dia., 2 1/2" width) coated by P&M Coaters of Toronto
- FASCO PSC electric motor custom construction

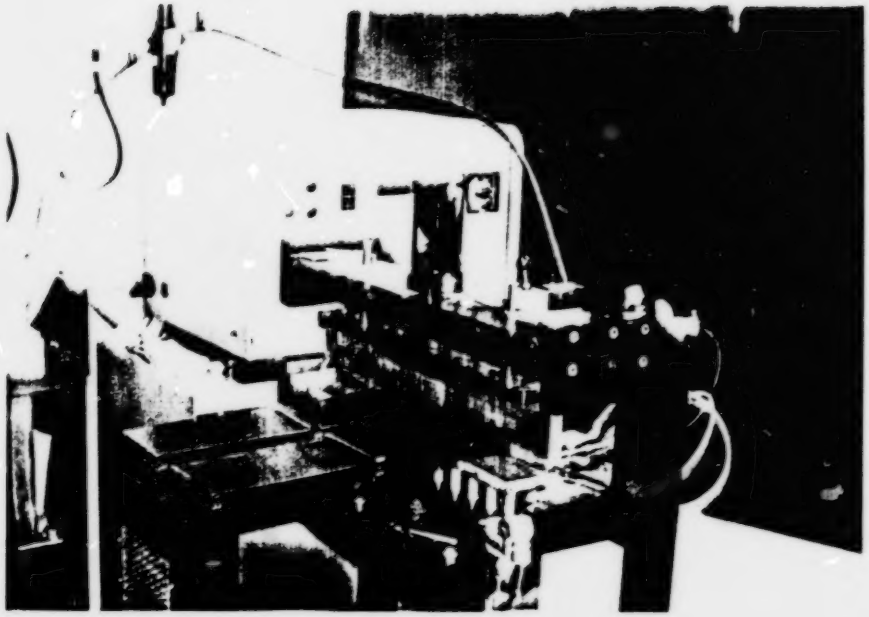


Figure B1: Electro-Magnetic Welding Machine

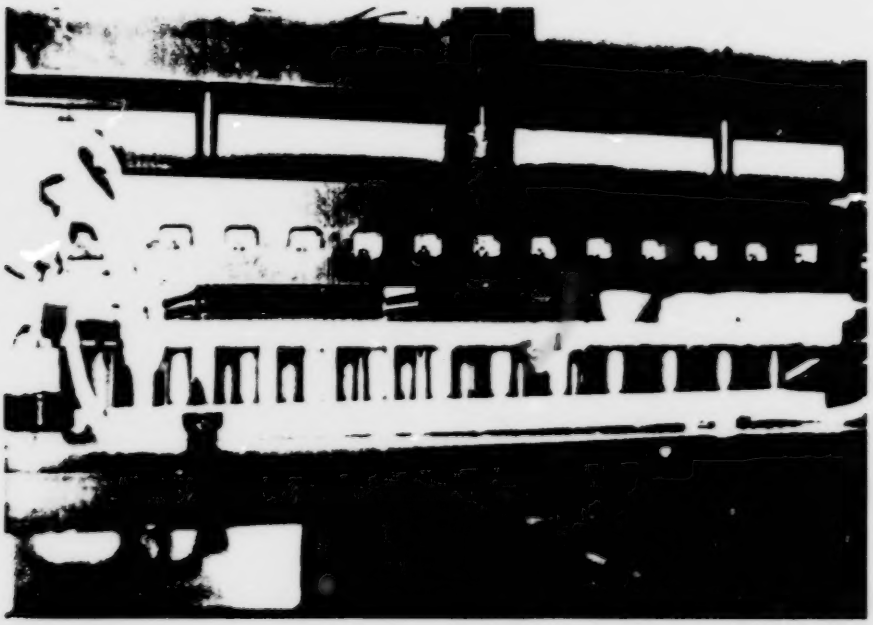


Figure B2: Sheet Assembly

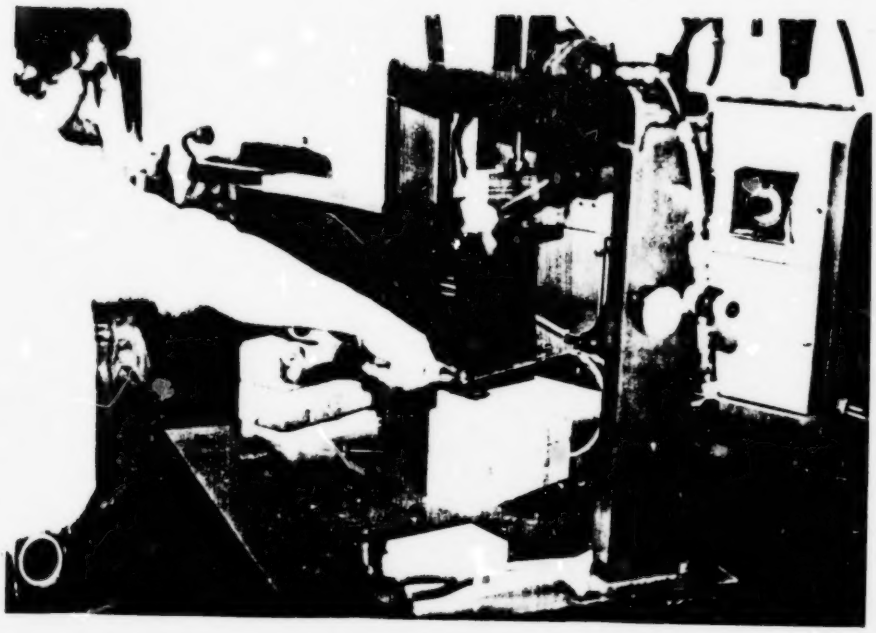


Figure B3: Module Assembly

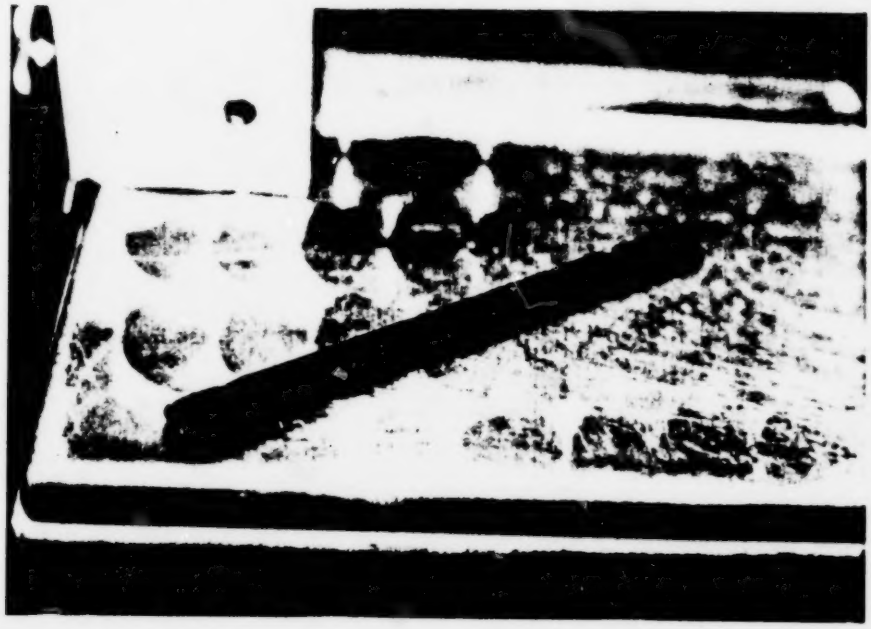


Figure B4: Spacer with Electro-Magnetic Weld Material